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front and back cover: Detail of a Kurdish kilim from the Van-Hakkari region. Two widths sewn together. One panel 28-29 inches wide; other panel 29-30 inches wide. Length (warp direction) 87-88 inches, plus approximately 8-inch braided fringe at either end. Weft count: 44-46 per inch (2.5 cm). Warp count: 10 per inch (2.5 cm). T. M. 1973.5 Color transparency by Raymond L. Schwartz.

PRINCIPLES OF TEXTILE CONSERVATION SCIENCE NO. XVII

Solutions and Other Mixtures for Cleaning and Conservation of Textiles and Related Artifacts

James W. Rice

Chemical substances for treatment of textiles are seldom applied full strength. They are usually mixtures containing other ingredients much diluted. The reason for this is that some beneficial chemicals are often damaging when used in high concentrations but work efficiently and safely at low concentrations. Perhaps a few definitions by what we mean by some of the terms used in the language of solutions together with how to prepare them will be of value to the Conservator.

Solutions

First, we may define a *solution* as a mixture of two or more substances dissolved in a solvent. A mixture is one of the three forms of matter; the other two being elements and chemical compounds. The substance that does the dissolving is the *solvent*, the matter dissolved is the *solute*, and the resulting mixture is the *solution*. In a *true solution*, the solute is equally distributed throughout as individual molecules or atoms. Usually this homogenous distribution has to be helped by mechanical mixing or heating. In appearance it will be clear, not foggy, in a beam of transmitted light as demonstrated by the Tyndall test.[1] It may be colored if the solute is a colored molecule.

From the point of view of content of solute, the solution may be *dilute* if it holds a relatively small amount of the dissolved substance. If it holds a relatively large quantity, it is *concentrated*. The actual amount of a solute that can be held in solution in any particular solvent depends on the temperature. As a rule, more solute can be dissolved at higher temperatures and greater concentrations attained. There are a few substances that do not obey this rule, however. Eventually, a solvent may not dissolve any more of a particular solute at a given temperature. At this point the solution is said to be *saturated* and if it is cooled, crystals of the solute begin to form and deposit out. Occasionally, if not disturbed in cooling, the deposit does not occur at once. At such times it is *supersaturated* but the excess will separate immediately on being disturbed.

The term *concentration of a solution* means a definite quantity of solute. In textile conservation work these quantities are nearly always reported as percentages by weight of solute in the total weight of the solution. Thus a two percent solution would mean 2 parts by weight of solute in 100 parts total weight of solution or 98 weight units of the solvent. This system is popular for concocting stock solutions. We may define a *stock solution* as one that is the basis for subsequent dilutions which we may differentiate by the name *use solutions*. The *use solution* is the concentration of the solute in question, recommended as the final treating bath for the textile or artifact in recipes, instructions, or procedure plans. Simple mathematical formulae with illustrative problems in the latter part of this article entitled *How to Dilute Concentrated Stock Solutions for Use* further explain the practical employment of these two terms.

Stock solutions with water as the solvent are simple to make by weight considerations, especially if one uses the metric measurement system of grams and milliliters. In this, a milliliter (ml) or cubic centimeter (cc) of water weighs one gram (g) at 4°C. In mixing, it is customary to dissolve a weighed quantity of the solute into a convenient part

of the total volume of solution first and then add enough make-up water to achieve the total volume. Minute differences in volumes between 4°C and room temperature (20°C) are neglected. Where it is not convenient or advisable to measure a liquid solute by weighing, volumetric measurements may be substituted. In this case, one needs to know the specific gravity of the liquid. Then by dividing the percent weight of the desired stock solution by the specific gravity one may obtain the volume of the solute. For example, if concentrated sulfuric acid has a specific gravity of 1.82 and a 10% stock acid solution is desired, the volume of the strong acid needed would be 10/1.83=5.5. Thus we should *add* 5.5 ml of the concentrated acid to 90 ml of water and after stirring and cooling, make the volume up to 100 ml. (This also illustrates a safety rule for making dilutions of acids, especially sulfuric acid. Acid is always added to water, never water to acid, because the solution may boil suddenly. The mixing should be done slowly.)

If, instead of water, the solvent is a drycleaning agent, the specific gravity figure again comes into play. Also, for ease in measuring, we may want to find the volume of a convenient weight of the solvent as for example, Stoddard solvent. Because this is a variable mixture of different hydrocarbons that are mainly composed of duodecane ($C_{12}H_{26}$) we may find in handbooks a figure of Sp.gr.= 0.7511[2] for the main ingredient.

Assuming that we would want 1000 grams of the stock solution, the calculated total volume would be 1000/0.75= 1333 ml. (In this calculation, disregarding the final two digits of the fraction will not make an appreciable error in the calculation.) The solute may either be weighed or measured volumetrically as explained by the example of diluting sulfuric acid.

Some drycleaning solvents such as perchlorethylene or trichlorethylene have higher specific gravity figures than the previous example. Thus 1000 grams of perchlorethylene with a Sp.gr. of 1.62[3] will have a volume of 1000/1.62= 616 ml, approximately, while trichlorethylene Sp.gr. 1.46[3] will have a kilogram volume of about 685 ml.

Other Physical Mixtures Resembling True Solutions

The textile conservator will often have occasion to employ liquid mixtures which are not true solutions in the sense that they are composed of fluids containing finely divided particles of solids or other liquids which are much larger than single molecules. In either case there are two phases, a *dispersed* phase corresponding to a solute and a *continuous* phase corresponding to the solvent. When the dispersed phase is a liquid, we call the mixture an *emulsion;* when it is a solid, we may distinguish it as a *suspension,* although some authors also include emulsions under this designation.

Emulsions and suspensions are very frequently encountered in textile cleaning. For example, most soaps and detergents when dissolved in water in an effective working concentration must contain a favorable concentration of micelles[4]. This means that the cleaning agent in reality is not exactly a solution according to definition but is also an emulsion because the micelles are larger than molecules and are probably not in a precisely homogenous distribution.

The practical use concentration of these detergents (and soaps) is very dilute, in the neighborhood of 0.18 to 0.25 per cent by weight of the active ingredient. Above about 0.5 per cent, the mixture becomes thicker and may form a *gel* especially if cooled. These gels usually are sufficiently homogenous, however, to be used as stock solutions for dilution with water to use conditions.

Such an emulsion, as first described, is called a *colloidal system* which is formed by scattered dispersed particles of exceedingly small size.[4] Up to this point we have been describing a *hydrophilic colloidal system* which means that there is great attraction between the colloidal particles (soap or detergent) and the dispersing medium, (water). An emulsion of this sort lends itself readily to dilution with water and with hydrophilic liquids like alcohol and glycerin.

The hydrophobic colloidal system is a second type wherein there is very little attraction between the dispersed particles and the continuous phase.

In order to produce a successful emulsion of this type, the particle size must be very small and the differences in attraction (or repulsion) must be overcome by employing a suitable surfactant[5] which we will call an *emulsifying* agent. A good illustration of this type of system is found in "Charged System Drycleaning".[6] In this process, a drycleaning detergent (the emulsifier) which will dissolve in a small amount of water is in turn dispersed in the solvent which is hydrophobic. The concentration of drycleaning soap varies according to the soil condition of the goods from 3/4 to 4 per cent. The concentration of moisture in the drycleaning detergent is rarely more than 1 or 2 per cent, so that the water content of the charged solvent may range according to chosen cleaning conditions from 75 ppm (parts per million) up to 800 ppm. This moisture is actually in emulsified form and is able to carry away most water soluble soils such as salts, sugars and some water soluble colored staining substances.

How to Dilute Concentrated Stock Solutions for Use

Where possible we try to make our standard stock solutions at 10 per cent concentration. But, because of differences in maximum saturated concentrations, some solutes will not dissolve to that point at ordinary temperatures. When this happens, we choose some lower percentage composition for our standard stock. This can be calculated as we will show below if one remembers that if you take a given weight of a solution containing a known weight of solute and dilute it to some other weight, the *amount* of solute remains the same although both the percentages and the total weights change. A mathematical relationship can then be proven which is valuable for calculating the various changes. This is expressed by a simple algebraic formula which says that the weight of solution times the per cent of the solute is W × P where W is the total weight and P is the per cent of the solution. This may be expressed by W × P = weight of solute.

If we let Wc = total weight of the solution taken for dilution
Pc = the per cent of solute therein
Wd = total weight of the resulting diluted solution
and Pd = per cent of solute when diluted
then (1) $Wc \times Pc = Wd \times Pd$
or weight of known solution used to make any chosen weight of dilute solution may be found by the algebraic formula

(2) $$Wc = \frac{Wd \times Pd}{Pc}$$

The weight of solvent Wa added is

(3) $Wd - Wc = Wa$ where a means added solvent

Practical Use of Dillution Formulae

Perhaps an illustrative problem will be of value in demonstrating how to use the mathematical formulae just mentioned.

Suppose we have a cotton-printed fabric from which colors bleed upon testing with plain tap water and with detergent. However, by experiment we find that the colors are set by a two per cent solution of salt containing about one-half per cent Orvus W.A. jelly. For cleaning and removal of the soil from approximately one pound of material we will need some twenty pounds or roughly twenty pints of bath solution.

We have on hand a stock solution of 10 per cent pure table salt (non-iodized) and a stock solution of 10 per cent of Orvus jelly. (We choose this detergent because it is not appreciably affected by salt brine, whereas soap would be.)

If the piece of material weighs one pound and we hope to clean it by soaking, how much 10 per cent brine and how much Orvus stock will we need for the bath?

Referring to equation (2) above, we write down:

$$(2)\ Wc = \frac{Wd \times Pd}{Pc}$$

From our known information, we can list the various factors thus:

Wc = unknown
Wd = 20 pounds (approximately pints)
Pc = 10 (in each case)
Pd = 2 for the salt brine
Pd = 0.5 for the Orvus

Solving for the amount of 10 per cent brine stock needed we have:

$$Wc = \frac{20 \times 2}{10} = 4 \text{ pounds or pints of brine}$$

and $$Wc = \frac{20 \times 0.5}{10} = 1 \text{ pound or pint of detergent stock}$$

(3) Water added $Wa = 20 - 4 - 1 = 15$ pints or pounds

(It should be noted that the pint of water actually weighs 1.04 pounds but in this case the difference (0.04) may be neglected because the cleaning recipe is here a matter of judgment from experience and the fraction of error is very small.)

Another Common Example—Dilution of Commercial Acetic Acid (28%) to 10% Stock

Concentrated acetic acid is sold by laundry and cleaning suppliers at 28 per cent concentration. While this can be used safely for special spotting purposes, it must be diluted for "souring" and dyesetting purposes, so the conservator may have need for the intermediate stock of 10 per cent concentration. The following calculation is given as an illustration:

$$(2)\ Wc = \frac{Wd \times Pd}{Pc}$$

Wc = amount of 28% acid to be measured, unknown
Wd = weight or volume in pounds or pints of water in the storage bottle. Let us assume our stock bottle is a 5 gallon or 40 pint size.
Pc = 28%
Pd = 10%

substituting in (2) $Wc = \frac{40 \times 10}{28} = 12.125$

or about 12 pints and 2 ounces if measured by the U.S. system for measuring liquids.

Thus we would measure out this quantity of 28% acid into the large stock solution bottle and fill it up to 5 gallon mark with water.

Appendix

For purposes of calculating solutions for most uses in Textile Conservation Work the following factors and formulae are furnished:

1. *Useful data*
   a. 1 cc or ml of water weighs 1 gram
      1000 ml of water weighs 1 kilogram
      This is when measuring quantities in the C.G.S. or metric system.
   b. When using the standard U.S. or avoirdupois systems, the following are close approximations:
      1 gallon of water weighs 8 1/3 pounds
      1 gallon equals 8 pints
      1 pint equals 16 ounces fluid
      1 pint of water weighs 1.04 pounds
      1 ounce of water weighs 28.3 grams
      1 pound of water weighs 453 grams
      1 gallon of water occupies 231 cubic inches
      1 cubic foot of space will hold about 7 1/2 gallons of water
      1 cubic foot of water weighs about 62.4 pounds
2. *Mathematical formulae for calculating volumes of tanks and containers:*
   a. Volume of oblong boxes or basins:
      L = length, w = width, d = depth
      $V = L \times w \times d$
      when measured in inches V/231 = gallons
      when measured in centimeters V/1000 = liters
   b. Volume of a cylinder:
      $V = 3.14 \times R \times R \times H$
      where R is 1/2 the measurement across the top of the cylinder (diameter) and H the height of the cylinder.

Notes

[1]James W. Rice, General Chemical and Physical Structural Features of Natural Textile Fibers, pp. 47-51, in Principles of Textile Conservation No. I, *Textile Museum Journal*, Vol. I, No. 1, 1962.

[2]L. Sheflan and M. B. Jacobs, The Handbook of Solvents, p. 220. D. Van Nostrand Co., New York, 1953.

[3]James W. Rice, Table I, page 24 of Drycleaning of Fine and Fragile Textiles in Principles of Textile Conservation Science No. VIII, *Textile Museum Journal*, Vol. II, No. 2, 1967.

[4]John P. Lewis, An Outline of First Year Chemistry, ch. XXXIX, 6th ed. Barnes and Noble, New York, 1945.

[5]James W. Rice, Characteristics of Detergents for Cleaning Historic Textiles, pp. 23-33, in Principles of Textile Conservation Science No. VII, *Textile Museum Journal*, Vol. II, No. 1, 1966.

[6]James W. Rice, Drycleaning of Fine and Fragile Textiles, pp. 21-33, in Principles of Textile Conservation Science No. VIII, *Textile Museum Journal*, Vol. II, No. 2, 1967.